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**MEMORANDUM REPORT
M62-26-1**

**A TECHNIQUE FOR MELTING AND CASTING
MAGNESIUM-LITHIUM ALLOYS**

by

**A. SAIA
and
R. E. EDELMAN**

**OMS Code 5010.11.84200
DA Project 593-32-007**

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**FRANKFORD ARSENAL
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Frankford Arsenal
Philadelphia 37, Pa.

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A TECHNIQUE FOR MELTING AND CASTING
MAGNESIUM-LITHIUM ALLOYS

Prepared by:

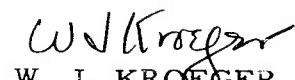

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ABSTRACT

A simple technique for melting and casting magnesium-lithium alloys is described. After melting in an argon atmosphere without flux, the molten metal is poured into a mold made of steel, machined graphite, or rammed graphite. Two pouring methods may be used, depending upon the size and shape of the ingot or casting.

Recommendations for future work are made.

INTRODUCTION

The magnesium-lithium base alloy system is of interest to the Ordnance Corps because of its high strength-to-weight ratio. These alloys offer up to 25 percent weight saving over conventional magnesium base alloys. The present effort at Frankford Arsenal is directed toward the development of a simple technique for casting ingots and shapes of magnesium-lithium alloys. The ingots are processed into wrought sheet for various experimental studies. It is also desired to develop a practical foundry technique for producing shaped castings.

Two major factors have hampered the development of efficient foundry techniques: (1) a method of melting and transferring the metal to a mold without any reaction between the molten metal and the surrounding atmosphere, and (2) a suitable nonreactive expendable mold for shaped castings.

Jackson et al^{(1)*} described a method for making small heats. Magnesium, lithium, other alloy additions, and flux were charged into a closed steel crucible. The crucible was heated and, during the meltdown, the molten surface was protected by a flow of argon. Alloying was promoted by stirring the molten metal. Time was then allowed to permit the flux to separate from the metal. After this settling time, the metal was poured into steel or graphite molds which were filled with argon. The molds were then capped and an argon atmosphere was maintained until the casting had solidified.

Larger heats were prepared in an open steel crucible having a diameter approximately 1/3 its height. Magnesium and alloying elements other than lithium were melted under a flux cover of dried lithium chloride (75%) and lithium fluoride (25%). The lithium was added by plunging it beneath the surface of the molten bath. After the melt was stirred thoroughly, the flux was allowed to settle and the metal was poured.

A more recent development⁽²⁾ has been the induction melting of heats weighing 75 to 100 pounds. The system is completely enclosed and protected by an inert gas. Sound ingots were produced by this method, but it is relatively expensive.

*See BIBLIOGRAPHY

MOLDS

Two types of mold were used. The first of these was a twin tensile bar mold, machined from steel (Figure 1). Before use, the mold was sand blasted and heated to 500° F. The hot mold surface was sprayed with a wash of the following composition:

Sodium silicate	35 grams
Bentonite (Western)	60 grams
Water	465 c.c.
Aqueous boric acid solution (saturated)	5 c. c.

Just prior to casting, the mold was again heated to 500° F.

The second type of mold employed in this investigation was produced from a rammed graphitic mixture. The general method of mold preparation has been described in previous reports;^(3, 4) the specific procedure is presented in Appendix I. These molds were also coated and heated prior to casting.

FURNACE DESIGN

There are two important requirements in the design of a suitable furnace. The first is that the melting be carried out in a closed vessel to prevent oxidation; the second is that melting be done in a flux-free crucible in order to eliminate any possibility of flux inclusions.

Using these design criteria, a furnace of 75 pounds capacity was designed and constructed (Figure 2). The crucible is a mild steel pot of the type commonly used for melting magnesium. The top portion of the crucible, which had the pouring lip removed, was fitted with a steel cover plate. Figure 3 is a schematic illustration of the furnace. A charging port was welded to the top for the addition of lithium and other elements after the magnesium had been melted down. A seal for manipulation of the stirring apparatus,

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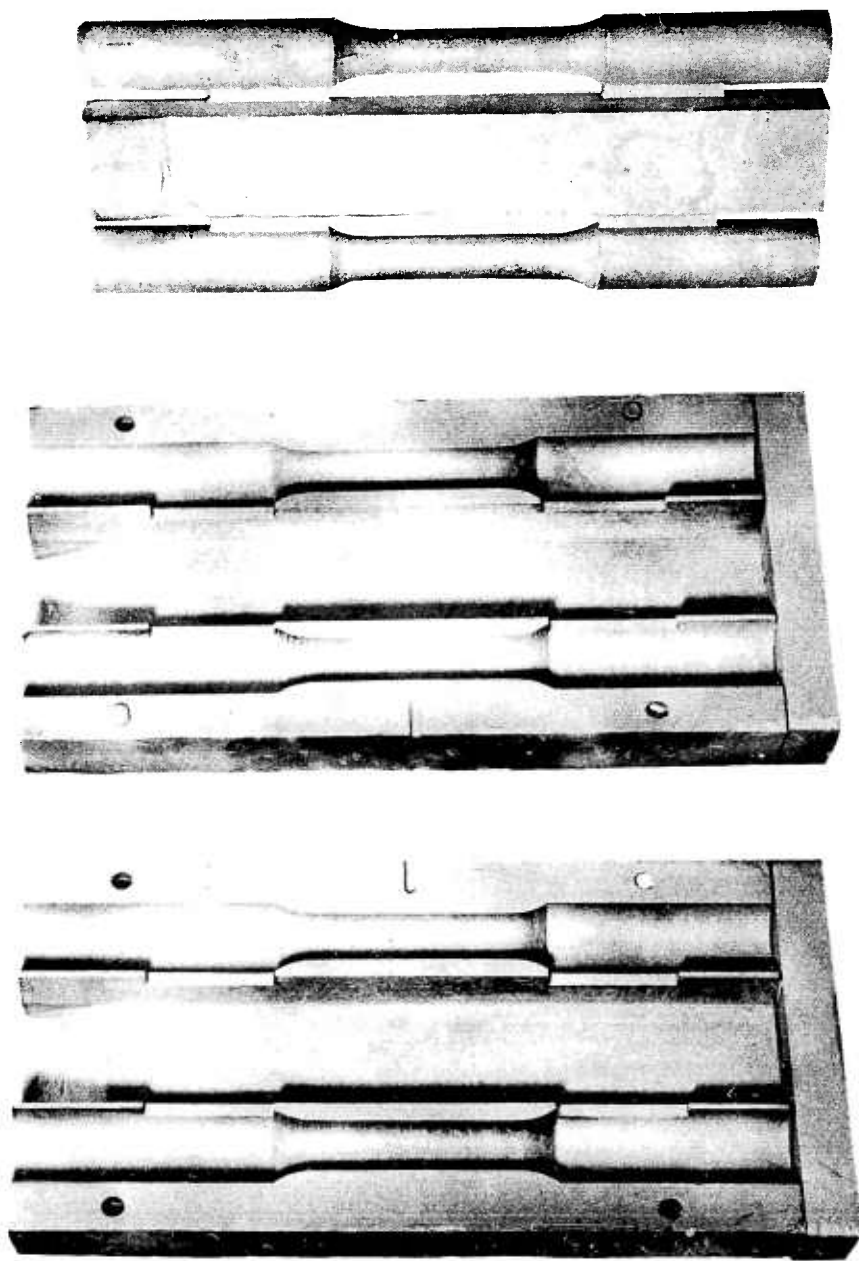


Figure 1. Test Bars and the Split Permanent Mold in which they were cast

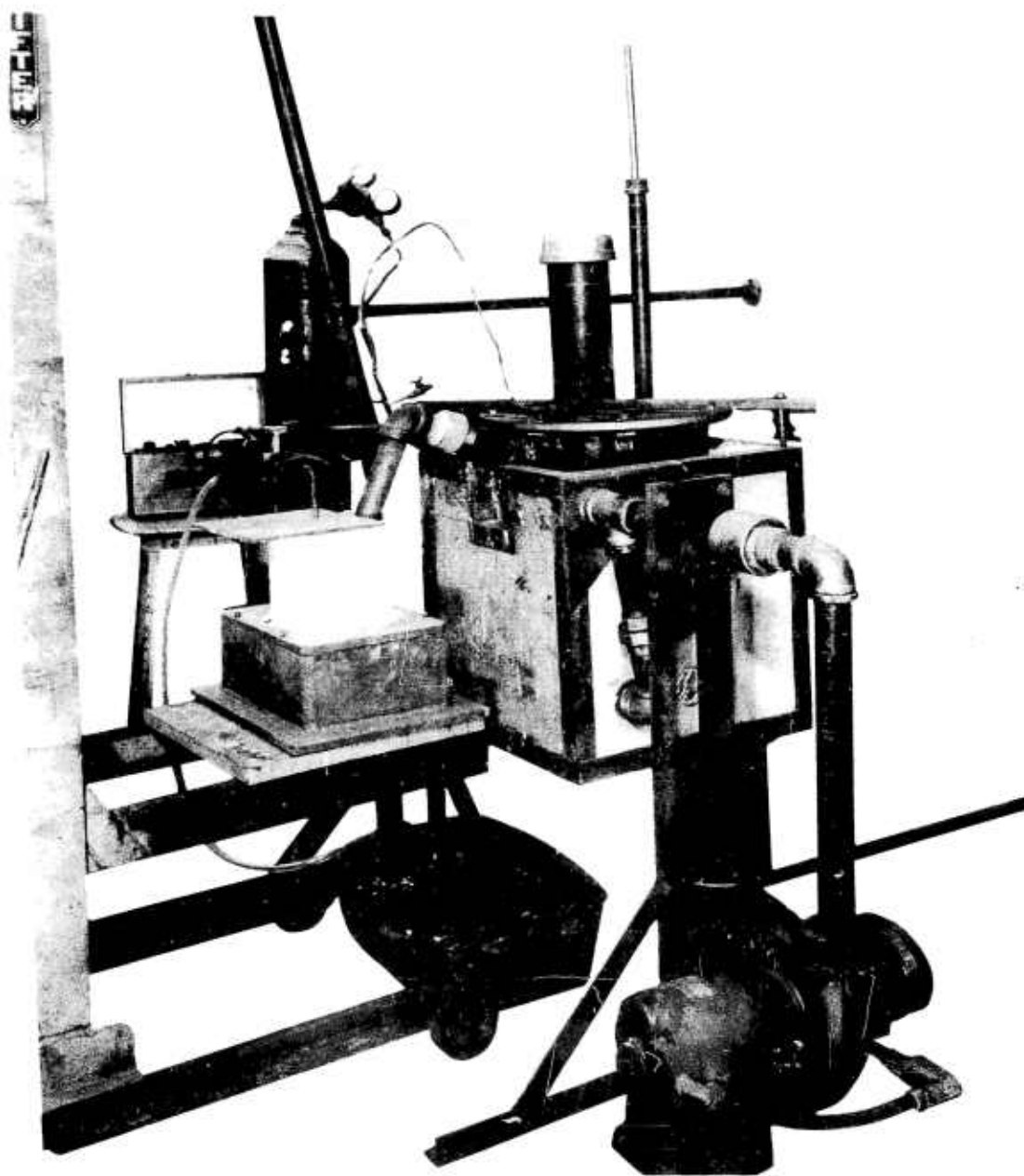


Figure 2. Magnesium-Lithium Furnace showing Mold in position preparatory to pouring

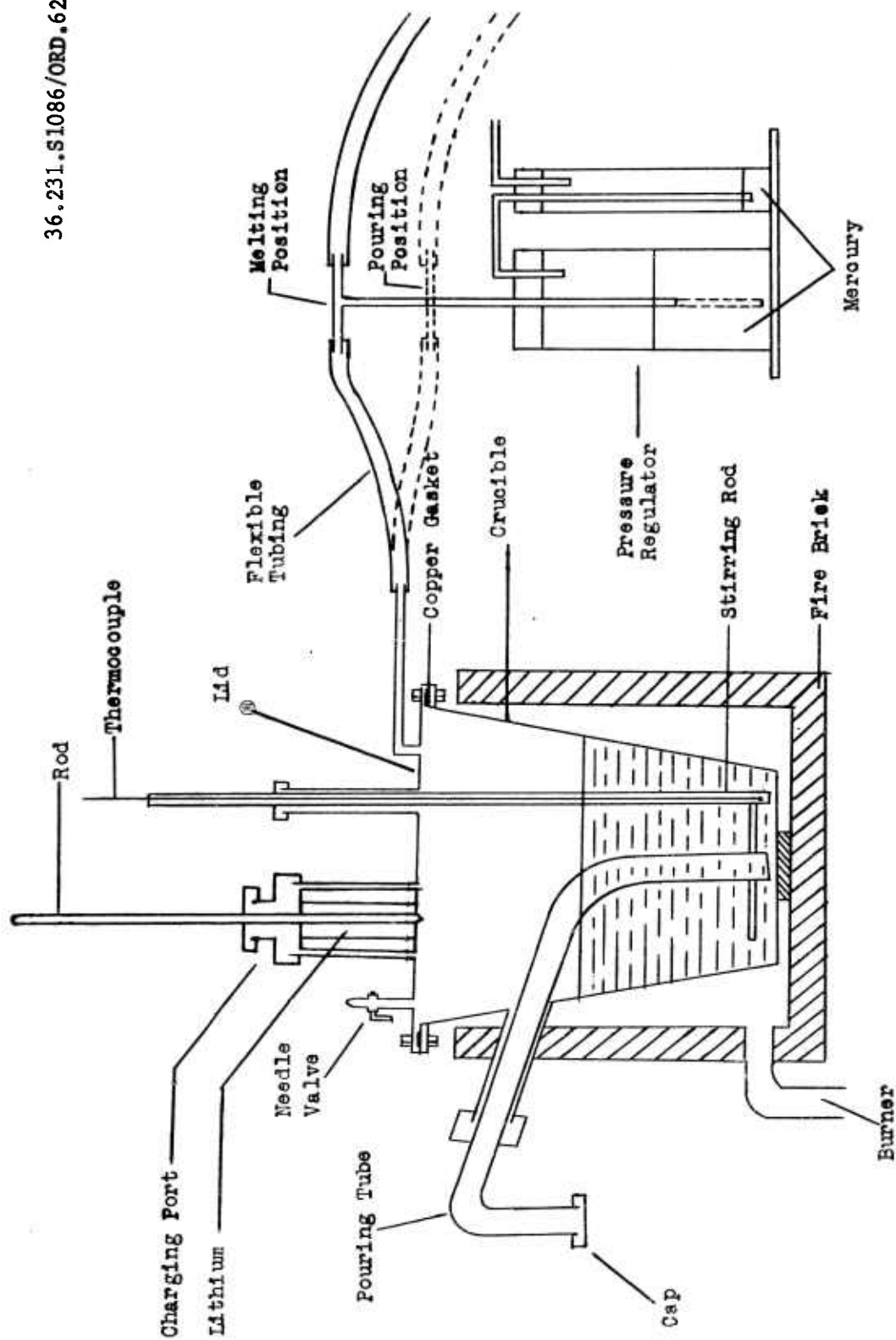


Figure 3. Cross Section of Mg-Li Melting Furnace

which also contained the thermocouple, was fitted to the lid. A gas seal was obtained by insertion of a copper gasket between the lid and the top of the crucible. The pouring tube, on the side of the crucible, was capped during melting. Argon gas was introduced through the lid. An argon flow was maintained to compensate for the leakage in the system.

A needle valve, installed in the lid, could be opened to permit flushing with argon prior to the melting operation. The metal could be pumped through the pouring tube by increasing the argon pressure so that it would force the metal out through the tube. Figure 3 also shows a schematic representation of the pressure regulator apparatus which controlled not only the protective atmosphere, but also the metal pumping operation. The pressure for maintenance of the protective argon atmosphere was controlled by the length of the column of mercury. Flow was so metered that bubbles would slowly escape from the lower end of the control tube. This eliminated the danger of premature pumping of the metal in the crucible.

To pump the metal, the control tube was lowered to the pouring position (Figure 3). The pressure is thus increased within the system and the metal is forced out through the uncapped pouring spout. Pumping is stopped by raising the control tube to the melting position. A second mercury bottle is attached to the pumping bottle so as to provide a one-way valve. This valve prevents the aspiration of the outside air should the internal pressure of the system suddenly drop.

The pumping mechanism was used for large castings where the pour was uninterrupted. Where small castings had to be made and the pour had to be stopped between castings, the pumping technique could not be used because the metal tended to freeze in the pouring spout. An explanation for this behavior can be seen in Figure 3. The pouring spout is made of two concentric tubes. The inner tube carries the molten metal, while the outer tube contains the protective gas. Even heating the outer tube by means of an acetylene flame could not melt the metal. Where it became necessary to make several castings from the same heat, the pouring tube was removed and the crucible was tilted to pour. Simple design changes can be made so that the inner tube can be kept heated, thus preventing the freezing of the molten metal.

For small heats, a 10 pound capacity, resistance-wound furnace was constructed. This furnace operated similarly to the larger furnace. The pouring was done by tilting the crucible.

OPERATION

The steel crucible was washed with a 5 to 10 percent HCl solution and the acid was allowed to stand in the crucible for 24 to 48 hours. The acid solution was removed and the crucible was rinsed with clear water. After this operation the crucible was heated to approximately 500° F to finish the drying. The I.D. of the crucible was then sand blasted to complete the cleaning operation. No refractory coating was used in the crucible during melting.

The required weight of the magnesium was charged into the crucible. The crucible was sealed and purged with argon for 5 minutes. A small positive argon pressure was maintained during the melting cycle. The crucible was heated to 1300° F and held at that temperature while the alloy additions were made. The lithium and other alloying additions were fastened to a steel rod and pulled up into the charging tower prior to sealing the furnace. After the magnesium was molten, it was possible to plunge the lithium beneath the melt without breaking the argon seal. If additional alloying were necessary, the charging port cover was opened and the required additions were made. The charging port cover was closed and the rod was plunged into the melt. Care had to be exercised so that all the elements were pushed beneath the surface of the molten magnesium. The melt was vigorously stirred and allowed to settle for 5 minutes. The metal was then reheated to the pouring temperature (approximately 1325° F) and poured into the mold which was previously purged with argon. An argon cover was maintained during the pouring and until the metal was frozen.

The procedure outlined above was followed when shaped castings were made. When a billet was poured, the same melting practice was employed except that the end of the pouring tube was

brought close to the bottom of the mold to minimize turbulence and spatter. The mold was gradually lowered as it was being filled with the metal.

RESULTS

Ingots of various magnesium-lithium alloys have been cast, as well as a number of shaped castings. These particular shapes were chosen because the patterns were readily available. It was believed that these parts would give a good indication of the capability of producing both solid and cored castings. The mold for the telescope door cover was made of machined graphite, while the mold for the more complicated and cored instrument housing was formed from rammed graphite. Both molds were coated with the Bentonite mixture. Castings from both these molds (Figures 4 and 5) were sound.

CONCLUSIONS

1. Clean ingots of magnesium-lithium alloys can be cast.
2. Shaped castings of magnesium-lithium based alloys are feasible where the melting and casting is carried out under the proper conditions to prevent oxidation.
3. Steel, machined graphite, and rammed graphite can be used as mold materials provided they are coated with a non-reactive wash.

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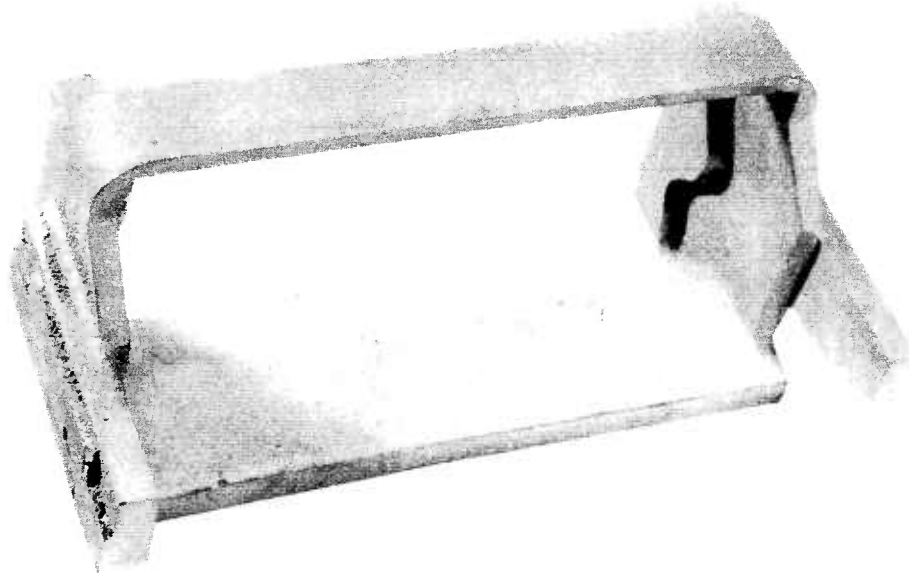


Figure 4. Carrier Block Vision Rotor cast in Magnesium-Lithium Alloy

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Figure 5. Telescope Door Cover for use in Experimental Tank

FUTURE WORK

Since this investigation has shown that not only ingots but cast shapes of magnesium-lithium alloys can be made, the next step will be the determination of the best foundry conditions, compositions, and mechanical properties of the alloys. A study of these properties has been started and will be the subject of a future report.

APPENDIX I

PROCEDURE FOR PREPARING RAMMED GRAPHITIC MOLDS

1. Composition

<u>Component</u>	<u>Weight Percent</u>
Graphite powder	64
Pitch (pulverized)	12
Carbonaceous cement	10
Starch	7
Water	6
Surface activating agent	1

2. Weigh the constituents shown above in the proper proportions.
3. Mull the dry constituents for approximately 30 seconds in a clean sand-type muller.
4. Mix the carbonaceous cement, surface activating agent, and water in a separate vessel.
5. Add the mixture of carbonaceous cement, surface activating agent, and water to the dry constituents and mull the entire mixture approximately 3 minutes.
6. Coat the pattern and inside of the flask with a suitable parting agent, such as a silicone spray.
7. Pack the graphite mold material around the pattern by conventional hand-ramming techniques until the flask is full.
8. The finish molding operation should be accomplished by jolting and squeezing. A minimum pressure of 100 psi should be applied to the mold during the squeezing operation.
9. Remove the pattern and the flask. Then air dry the mold for at least 2 days.

10. Heat from room temperature to 250° F at a rate of approximately 15° F/hr.; then hold for 6 hours at 250° F.
11. Pack mold in powdered graphite and heat to 1800° F; hold for 2 hours at 1800° F.
12. Cool mold slowly to room temperature.

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